EFFECT OF SIZE OF IRON ORE PELLETS ON ITS REDUCTION KINETICS

A THESIS SUBMITTED IN PARTIAL FULFILMENT
OF THE REQUIREMENT FOR THE DEGREE OF

Bachelor of Technology
in
Metallurgical and Materials Engineering

By

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&
NIRMAL CHAWLA

Department of Metallurgical and Materials Engineering

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Rourkela

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CERTIFICATE

This is to certify that the thesis entitled, "EFFECT OF SIZE OF IRON ORE PELLETS ON ITS REDUCTION KINETICS" submitted by Sri SUBASH CHANDRA SAHU & NIRMAL CHAWLA in partial fulfillment of the requirements for the award of Bachelor of Technology Degree in Metallurgical and Materials Engineering at the National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University / Institute for the any Degree or Diploma.

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Subash Chandra Sahu
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B.Tech
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CONTENTS

Page No.

ABSTRACT

A large number of industries in this world are now producing iron, either by the root of directly or indirectly. India is now not only producing iron ore pellets but also exporting it to other countries. Use of iron ore pellets not only increase the productivity of the plant but also produce good quality iron. So it is essential to know about the various factors which affect the reducibility of the iron ore pellet. In our project we aim at studying the effect of size of iron ore pellet on its reduction kinetics and in the course of our experimentation we aim at arriving at particular pellet size that gives both increases in productivity and decrease coke rate.

Pellets are approximately spherical lumps formed by agglomeration of the crushed iron ore fines in presence of moisture and binder, on subsequent induration at 1300°C.
In these times with the areas of iron ore use increasing, it is very important to use raw materials that not only increase the productivity of plant but also produce a better quality iron. Blast furnace raw materials have changed in character greatly in the last 2 or 3 decades. Formerly, they used to be raw iron ores, raw lime stone and coke. There are now being increasingly being replaced by pre fluxed sinter and pellets and liquid and gaseous fuels. Few examples of revolutionary changes brought to the present day iron making industries by use of pellets are Essar steel, TATA steel, Jindal Steel etc.

Reduction of various sizes of iron ore pellets were carried out with non coking coal in a stainless steel reactor of size 10*5 cm. The stainless steel reactor was half filled with non coking coal powder of size -72# and the weighed oven dried pellet was placed centrally on this non coking coal powder bed and then the remaining portion of the reactor was filled with coal powder then it was covered with an air tight cover having a hole for escape of gases. The reactor was introduced into a muffle furnace and soaked there for 1 hour. The reactor was then cool inside the muffle furnace up to 150^0C and then taken out and cooled in air and weight loss was calculated by electronic balance and hence % of reduction was calculated as [(Weight loss in iron ore pellet X 100)/ (Total initial O_2 present in iron ore pellet with iron)]

We can conclude that as we increase the size of iron ore pellet, this results in decrease in the reducibility of iron ore pellets. The most optimal size range for reducibility to be effective in industrial application is 10 mm to 20 mm.

LIST OF FIGURES

Page No.

LIST OF TABLES

Chapter 1

INTRODUCTION

1. INTRODUCTION

In these times with the areas of iron ore use increasing, it is very important to use raw materials that not only increase the productivity of plant but also produce a better quality iron. Blast furnace raw materials have changed in character greatly in the last 2 or 3 decades. Formerly, they used to be raw iron ores, raw lime stone and coke. There are now being increasingly being replaced by pre fluxed sinter and pellets and liquid and gaseous fuels. Few examples of revolutionary changes brought to the present day iron making industries by use of pellets are listed below:-

- Essar steel has set up a palletizing plant in Vizag of 2.2 MT capacity which uses iron ore from Bailadila. By this the productivity of Essar steel, Surat, Hazir, has increased from 0.7 MT to 1.1MT.
- Trial at TATA steel, Jamshedpur have shown that by using pellets a coke rate reduction of 20 Kg/tonne and increased in productivity by 0.7% has been achieved.
- As a result of introduction of pellets in the Ijamudin blast furnace a coke rate decreases of 20-22 kg/tonne was expected.
- Jindal has also set up a palletizing plant at Belgaon for pellets to be charged in COREX process.
- A 6.75 MT palletizing plant has been set up at Kudremukh, Karnataka which export pellets to various countries.

In our project we aim at studying the effect of size of iron ore pellet on its reduction kinetics and in the course of our experimentation we aim at arriving at particular pellet size that gives both increases in productivity and decrease coke rate.

Chapter 2

LITERATURE REVIEW

2. LITERATURE REVIEW

2.1 What are Pellets?

Pellets are approximately spherical lumps formed by agglomeration of the crushed iron ore fines in presence of moisture and binder, on subsequent induration at 1300°C.

2.2 Pelletizing

During mining and ore dressing operations, especially where very fine grinding is necessary for wet concentrations, a large amount of-0.05 mm fines is generated which are not amenable to sintering because of very low permeability of the bed. They can however be agglomerated by balling them up in presence of moisture and suitable additives like bentonite, lime etc. into 8-20 mm or larger size. These green pellets are subsequently hardened for handling and transport by firing or indurating at temperature 1200-1350^{o}C.

The balling stage is the most important part of the process and determines the strength, size compactness and other pellet properties. The operation is performed in rotating devices like drums, discs (with flange on the rim) and cones, the most used being the former two. The effectiveness of the plain can be increased by fixing daffles inside. The ball formation occurs because of the surface tension of the water forces and collision between particles. Initially, small nuclei of pellets are formed on addition of water and the nuclei grow bigger into balls and then into pellets as the peak of loose grain particles during their travel through the drum which is slightly tilted. The angle of tilt determines the time of residence, pellet size and productivity. The size and shape of the drum should be such as to obtain to most favorable conditions of motion and pressure that is more of rolling as opposed to sliding action. This is a more effective collision between the particles. The capillary action of water in the pores of the ball is sufficiently high so as to compact the constituent grains into a dense mass, the compressive force is directly proportional to the fineness of grain. Since, the capillary action rises with the decrease in the pore radius and the later decrease with increasing fineness. Optimum moisture is important since too little of water introduced air inclusions in the pores in too much of water cause flooding and destruction of capillary action. The optimum moisture content lays between 5-10%, the finer the grains the larger the requirement.

2.3 Advantages of Pellets

1. Good Reducibility

Because of there high porosity that is (25-30%), pellets usually reduced considerably faster than hard burden sinter or hard natural ores. In the earlier days of palletizing, considerable weight was given to means for securing porosity for higher reducibility.

2. Good bed Permeability

Because of their spherical shapes and containing open pores, these are formed very good bed permeability. The shape, size and low angle of repose give minimal segregation and an even charge distribution in the furnace, extending more towards the axis.

3. High Strength (150-250 kg/cm^2) or more

Pellets should have sufficient structural strength to with stand, without significant breakage, the normal handling which occurs in the various transportation and handling steps between the pellet furnace an the blast furnace skip.

4. High Porosity (25-30%)

Because of high porosity of pellets, these are easily reducible.

5. Less heat consumption than sintering

6. Uniform chemical composition

The chemical analysis is to degree controllable in the concentration processing within limits dictated by economics.

7. Easy handling and transportation

8. Good resistance to disintegration during furnacing

It is extremely difficult to determine what happens to pellet after it enters the blast furnace. Questions have arisen as to whether certain type of pellets might disintegrate in the furnace before they reach the smelting zone. Several tests have been advanced to measure this disintegration. One is the Linder test.

9. Resistance to weathering and freezing

Because pellets are subjected to extended storage from time of production to time of consumption, they must be resistant to physical breakdown caused by exposure to weather. Moisture and freezing are chief hazards.

Well fired pellets have 20-35% porosity, but pick up only about 3% moisture even after prolonged exposure of all kinds of weather. Freezing and thawing do not result in any significant breakdown. The effect of weathering give some concern if lime or magnesia are used either as an additives or to flux the pellet. Complete calcinations and chemical combination of these materials with the iron must be attained to prevent hydrolysis on weathering and resultant decrepitation.

2.4 Disadvantages of pellets

1. High cost of production due grinding and firing especially with oil burners.
2. Swelling and loss of strength inside the furnace.
3. Sticking during firing.
4. Resistance to flow of gas more than that in sinter for the same size range due to lower voidage.
5. Difficulty of producing fluxed pellets.
6. Fluxed pellets breakdown under reducing conditions much more then acid and basic sinter, acid pellets.
7. Stronger highly fluxed sinters, especially contain magnesia, are being increasingly preferred to pellets.
8. Maximum basicity of the pellets is 1.2.

2.5 Raw materials required for Pelletising

1. Iron Ore fines
2. Carbonaceous Materials
   e.g. Non-Coking Coal, Charcoal and Coke fines
3. Binders
   (i) Organic (Dextrine, Thermosetting resin, Processed or natural Oil)
   (ii) Inorganic (Bentonite, Cement, Lime, Calcium hydroxide, Olivine)
4. Moisture

2.6 Mechanism of Pelletizing

1. Ball Formation

Surface tension of water & gravitational force creates pressure on particles, so they coalesce together & form nuclei which grow in size into ball.

2. Induration (Heat Hardening)

Solid state diffusion at particle surfaces at higher temperature causes recrystallisation & growth giving strength. The force responsible for the agglomeration of ore fines are capillary action of water and gravitational force of particles. The ball forces occur because of surface tension forces of water and collision between particles. Initially, nuclei of pellet are form from addition of water and the nuclei grow bigger in balls and then into pellets as they pick up loose grain particles during there travel through the drum, which is slightly tilted the angle of tilt determines the time of residence, pellet size and productivity. The size and shape of drum should be such as to obtain the most favorable condition of motion and pressure that is more of rolling as offer to sliding motion. This ensures more effective collision between particles. The capillary action of water under interstitials of the grain causes a contracting effect on then. The pressure of water on the course of ball is sufficiently high so as t compact the constitute grain into a dense mass. The compressive force is directly proportional to the fineness of the grain since the capillary action rises if the decrease in pore radius and the later decreases with increase in fineness. When one particle falls and comes into the gravitational force filled of another particle of which it falls and its neighbors, they adhere because of pressure generated due to gravitational force. Due to this force tremendous amount of pressure is built up which leads to molecular adhesion. The green pellets obtain are then fired at 1100C to ensure complete removal of moisture and then these are heat hardened at 13000C or 1 hour in order to ensure the strength of pellets which is due to recrystallization and grain growth.

2.7 Reduction Reactions

- $3Fe_2O_3 + CO/H_2 = 2Fe_3O_4 + CO_2/H_2O$
- $Fe_3O_4 + CO/H_2 = 3FeO + CO_2/H_2O$
- $FeO + CO/H_2 = Fe + CO_2/H_2O$

- $Fe_2O_3 + C = Fe_3O_4 + CO$
- $Fe_3O_4 + C = FeO + CO$
- $FeO + C = Fe + CO$
- $3Fe + C = Fe_3C$
- $C + CO_2 = 2CO$

Reduction of iron oxide by carbon is known as Direct Reduction Reaction and reduction of iron oxide by CO/H_2 is known as Indirect Reduction reaction.

* $C + CO_2 = 2CO$ is known as solution loss reaction.

2.8 Sequential steps of Reduction of Iron Oxide

$$\mathbf{Fe_2O_3} \xrightarrow{+22\%\ \text{vol.}} \mathbf{Fe_3O_4} \xrightarrow{+4\%\ \text{vol.}} \mathbf{FeO} \xrightarrow{\text{Slight contraction in vol.}} \mathbf{Fe}$$

Hematite	Magnetite	Wustite	Metallic iron
(Hcp)	(Cubic)	(Cubic)	(Bcc or Fcc)

2.9 Kinetic steps in Reduction of iron oxide

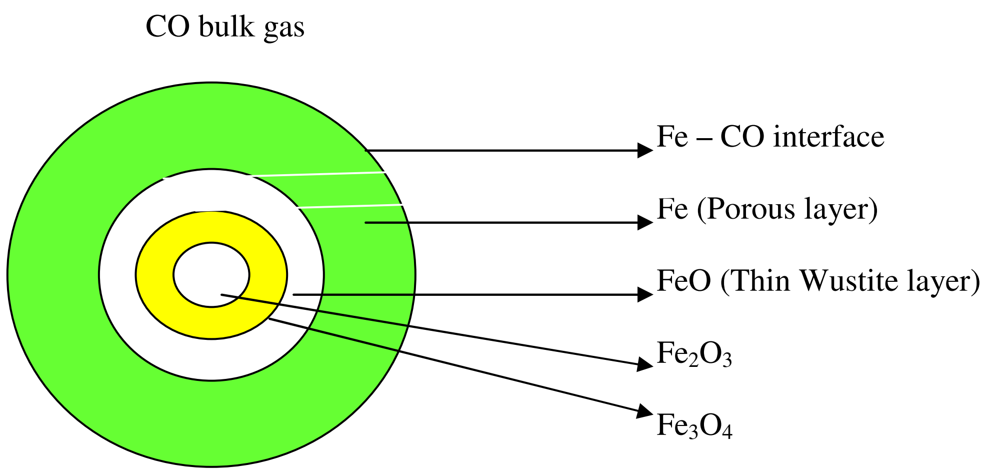


Fig: 2.1 a schematic diagram of the mode of gaseous reduction of iron ore

STEPS:-

1. Transport of CO gas from bulk gas phase to Fe – CO interface
2. Molecular diffusion of CO gas through Fe layer to the reaction interface.
3. Adsorption of the CO gas at the interface
4. Reaction between the Fe oxide & CO gas at the interface
5. Desorption of the product gas CO_2 at the interface.
6. Transport of iron & oxygen ions
7. Transformation in solid phase. Formation and growth of magnetite, wustite and iron.
8. Diffusion of CO_2 to surface
9. Desorption of CO_2 gas from the Fe – CO interface to the bulk gas phase.

Starting with a dense sphere of hematite, an initial reaction with CO or H_2 will produce a shell or layer of metallic iron in contact with a layer of Wustite beyond which there will be a layer of magnetite surrounding the core of hematite.

2.10 Determination of Reducibility

Reducibility is the ease with which the oxygen combine with the iron can be removed

It is represented by percentage fraction of oxygen removal, mathematically written as:-

% degree of reduction = $[(n_0 - n)/ n_0] X 100$

Where,

n_0 = *number of moles of oxygen originally present combined with iron*

n = *number of moles of oxygen left combined with iron after experimental time, t*

Reducibility generally measured in terms of $(dR/dt)_{40}$ & $(dR/dt)_{60}$

Reducibility of ferrous materials is characterized by the fractional oxygen removal rates in gaseous reducing atmosphere. The amount of oxygen removed is measure by weight loss of sample or through material balance of oxidized and reducing gas. The degree of reduction is plotted against time, the slope of curve giving the velocity of reduction at any time or at any particular of reduction. Since the reduction rate id critical after a metallic layer is formed from Wustite. The reducibility is generally compared at 40% degree of reduction.

However, by this process, hematite which contains more oxygen is compare unfavorably with magnetite. A more fair comparison is the rate of after 6o% oxidation level i.e. O/Fe = 0.9, which is the same at 40% reduction rate when two hematites or two magnetites are being compared.

2.11 Graph plotted between R (reducibility) Vs t (time of reduction)

The degree of reduction is plotted against time and the slope of the curve gives the velocity of the reduction at any time or any particular degree of reduction. Since the rate of reduction is critical after a matellic layer is formed from Wustite, the reducibilities are generally coated as (dR/dt) at 60%

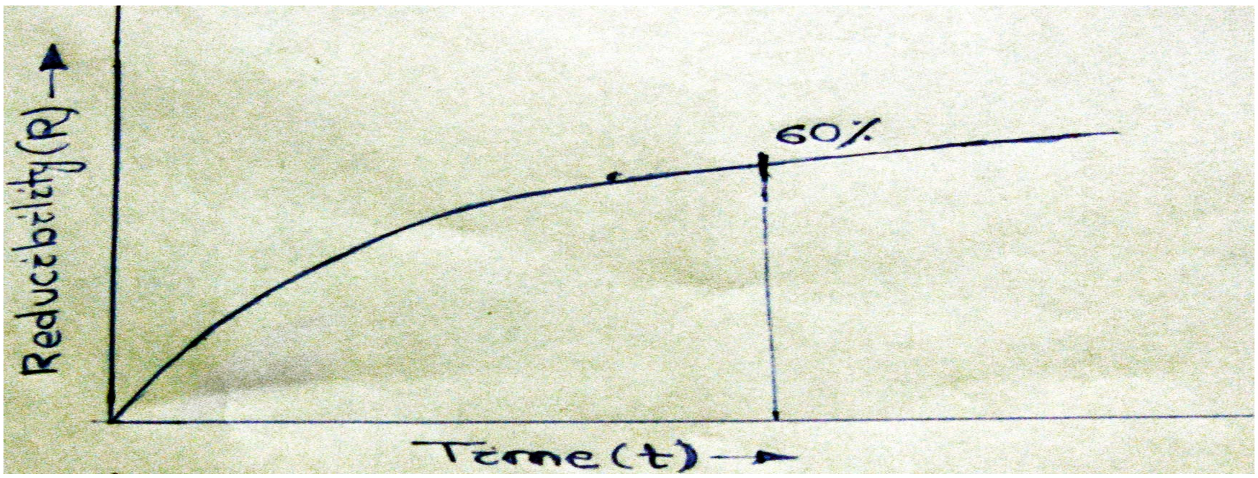


Fig 2.2 Graph plotted between R (reducibility) Vs t (time of reduction)

2.12 Factors affecting Reduction Kinetics of Iron Ore Pellets

1. Temperature of Reduction
2. Time of Reduction
3. Particle Size of Iron ore
4. Pellet Size
5. Flow rate of Reducing gas
6. Presence of Catalyst
7. Reactivity of Solid Carbon
8. Chemical nature of oxide
9. Fe_2O_3/C ratio

Chapter 3

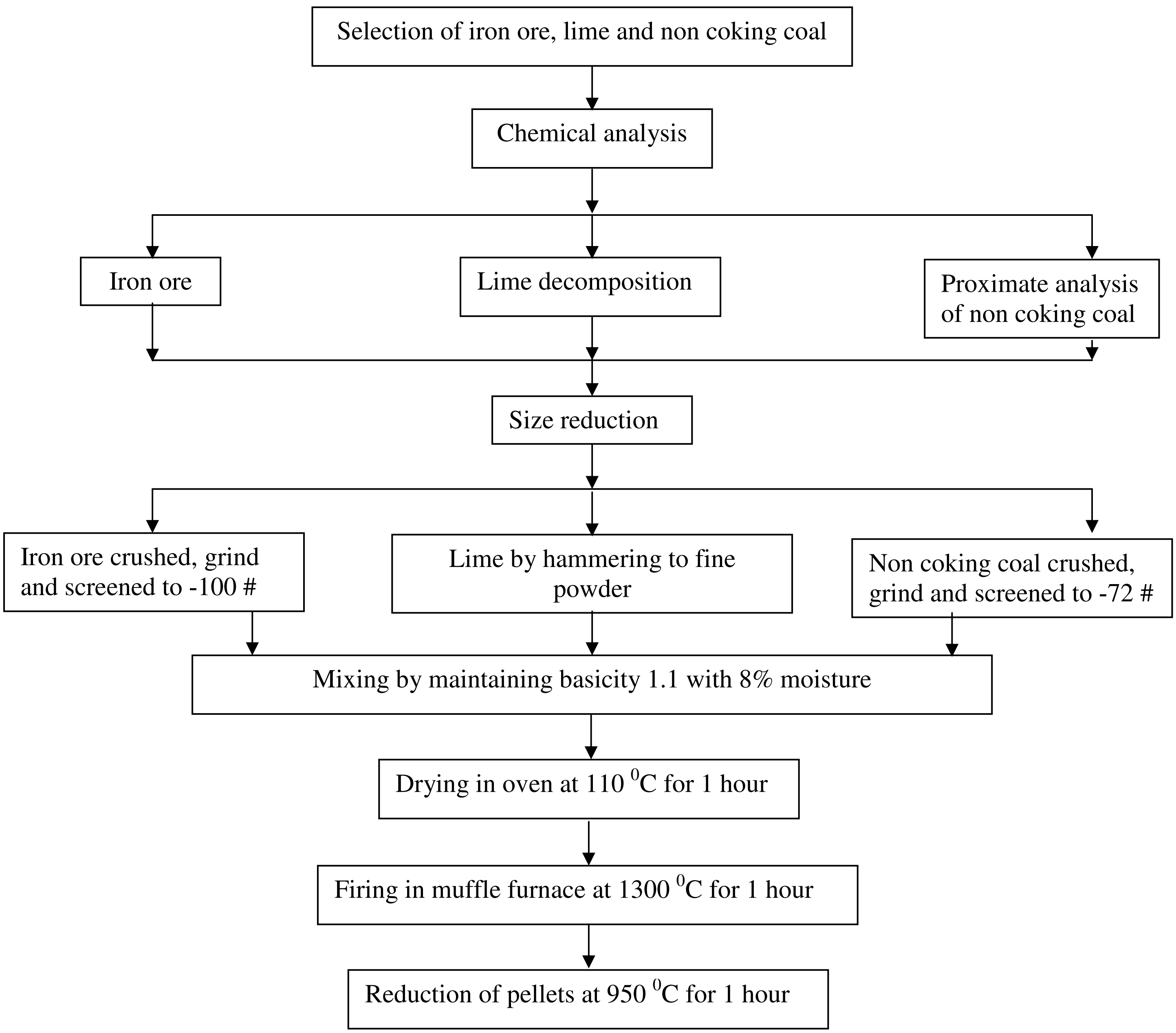
EXPERIMENTAL WORK

3. EXPERIMENTAL WORK

3.1 Aim

To study the effect of size of iron ore pellets on its reduction kinetics and other properties of iron ore.

3.2 Process flow chart



3.3 Raw materials required for palletizing

1. Iron Ore fines – BPJ OMC Ltd. (-100 #)
2. Carbonaceous Materials - Non-Coking Coal (-72 #)
3. Binders – Lime (B=1.1)
4. Moisture (8%)

Initially the iron ore was present in the form of lump we ground it to -100# size for the purpose of preparation of pellets and we found the chemical analysis of iron ore as follows:-

Fe	63.80%
SiO_2	2.3%
Al_2O_3	2%

Table: 3.1 Iron ore composition

From the above table we observe that the SiO_2 content in the iron ore is of 2.3%. So in order to maintain the basicity of pellet 1.1 it is essential to add 2.53% of lime.

But the lime available in the market is in the form of $caco_3$ whose composition is given as follows:-

$CaCo_3$	>=98.50%
Chloride	<=0.05%
Sulphate(So_4)	<=0.51%
Heavy metals (as Pb)	<=0.005%
Iron (Fe)	<=0.05

Table: 3.2 Composition of lime available in market

So it is essential to decompose the lime and during decomposition following reaction is taking place:-

$$CaCo_3 = Cao + Co_2$$

The necessary conditions required for decomposition of lime are temperature 940^0Cfor 1 hour in a muffle furnace.

3.4 Preparation of pellet

Mixing of iron ore fines (1 Kg), lime (27.2 gm) and moisture (8%)

Iron ore pellets were prepared from BPJ OMC Ltd. Iron ore mines (actually the iron ore was initially present in lump form. These were crushed and ground to fines of -100#)

The process of pelletization consist of rolling of moist iron ore fines of less than 100 mesh size with binder(lime) into balls of various sizes ranging from 5 mm to 30 mm according to aim of our project. Pellets were prepared by Disc pelletizer and Hand rolling.

Fig 3.1 Disc Pelletizer

3.4.1 Disc Pelletizer

It is essentially a disc, with an outwardly sloping peripheral wall, which is rotated, around its own center, in an inclined position to the horizontal as shown in the figure these discs resembles flying saucers and is inclined at about 45 degree to the horizontal. The material to be palletized is generally fed directly onto the disc and moisture level is made of with the help of water spray. Scrapper is provided to prevent build out of moist material on the disc it can also control material flow pattern on the disc. Disc Pelletizer used rotates at 15 rpm Pellets of size 5, 10, 11, 14, 15, 17; 20 mm were prepared by the use of Disc Pelletizer. We observe that after 1 hour the maximum size of pellet obtained was 20mm. So the pellets of higher size 22, 25, 27, 28, 30 mm were prepared by Hand rolling. In industries pellets are generally prepared by drum pelletizer or disc pelletizer.

3.4.2 Industrial drum pelletizer

It has the shape of pipe made out of steel, open at both ends with a length to diameter ratio of 2.5 to 3.5, rotating around its own axis in slightly inclined position to the horizontal. The drums are 2 to 3 meter in dia and 6 to 9 meter in length and rotate at 10 to 15 rpm depending upon the diameter. The angle of inclination in working position is about 2 to 10 degree. The charge is fed through that end which is at a higher level water sprays are also located there. The material rolls over the surface of the rotating drum and slides downwards due to inclination of the drum. This motion of the balls is called cascading which takes place until the balls emerge out of the lower eng there are some fundamental difference on the behaviour f a drum and disc pelletizer. The drum does not act as a classifier as does the disc and hence the time of ball growth is not equal to the residence time of the feed. The size range of output is therefore large and as a result it must be operated in close circuit with screen. The ball is usually effective in more that one passes through the drum.

Once the green pellets obtained are dropped from a height of 2 meters for about 4 to 5 times, in order to judge the quality of a green pellet. If there is no generation of fines then these are good quality pellets.

3.5 Drying of pellets

The green pellets then obtain were dried in an oven at a temperature of 110^{0}C for 1 hour. The main object of drying is moisture removal and ease of handling for further treatment.

3.6 Firing or Heat hardening of pellets

The dried pellets were then fired or indurated at a temperature of 1300^{0}C for 1 hour. In firing operation, the pellets (content in fireclay crucible) were hated from RT to 1300^{0}C slowly in oreder4 to minimize the thermal stress development and hence crack generation then soaked for 1 hour followed by furnace cooling. Once the pellets were prepared they are subjected for the evaluation of properties whether these are suitable for reduction or not.

3.7 Evaluation of properties of pellets

3.7.1 Porosity: - porosity content of pellets determines its reducibility higher the porosity greater the reducibility. There are two types of pore present in pellets these are open pores and close pores. True porosity and hence close porosity can be determined from open porosity which can be measured from true and bulk density although reducibility increase with increase in porosity which is calculated as follows:-

App. Porosity = (W-D)/ {(D-(S-s)} X100

Where,

W=Wt of water saturated sample in air

D=Wt of oven dried pellet

S=suspended wt of sample + thread in cold water

s=suspended wt of thread in cold water

Table: 3.3 Measurement of apparent porosity

Sl. No	Size of Pellet (mm)	D (gm)	S (gm)	S (gm)	W (gm)	S-s (gm)	Apparent Porosity	Average Porosity
1	25	28.7849	25.505	2.829	30.116	22.676	21.79%	22.87%
2	25	29.5847	26.444	2.829	31.027	23.615	24.17%	
3	26	31.3640	27.603	2.829	32.857	24.774	22.65%	

The average porosity in pellet was found to be 22.87% by hot water boiling method is little less than the theoretical value of apparent porosity (i.e. 25-30%) because of the initial iron ore fines of size -100#. If it was -325# size than the porosity could be up to the theoretical value.

3.7.2 Crushing strength

Crushing strength = P/A

Where,

P = load at breaking in kg

A = cross sectional area of pellet in cm^2

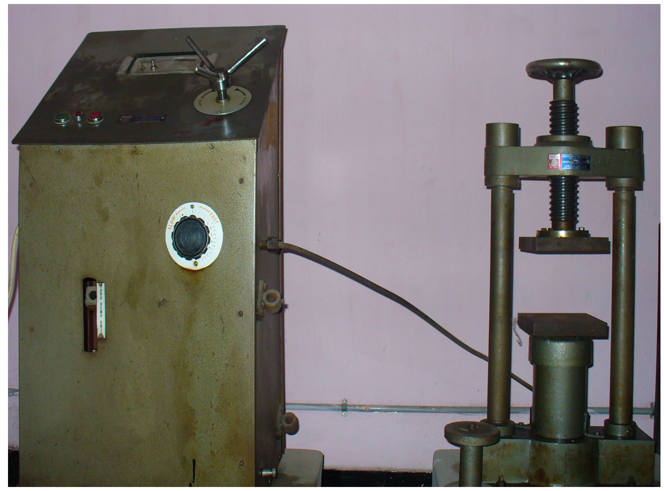


Figure: 3.2 Crushing strength measuring instrument

Table: 3.4 Measurement of crushing strength

Sl. No.	Size of Pellet (mm)	Load (Kg)	Area (cm^2)	Crushing Strength (Kg/cm^2)
1	25	1310	4.90	267.31
2	25	1280	4.90	261.22
3	16	600	2.01	298.50
4	11	260	0.95	273.68

In a furnace, whether the ore as charged will maintain there size depends on there strength. They should be resistant to abrasion and possesses high crushing strength there breakage in the furnace de to impact, abrasion, compression and volume change at high temperature in reducing atmosphere generate smaller particles, resulting in choking of voids hence the purpose of size grains.

The crushing strength was found to be more than 250 Kg/cm^2 (i.e. theoretical value). It was because of the formation of calcium ferrite (FeO.CaO.SiO2) phase during heat hardening.

3.8 Preparation of coal powder

In this project we have taken non coking coal for the reduction of iron ore pellets. Initially the non coking coal was in lump form. We crushed and Grinded the coal to -72# size. Crushing and grinding was done respectively in Jaw crusher and Ball mill. Then proximate analysis of the coal was done i.e. as follows:-

Table: 3.5 Proximate analysis of coal powder

% Moisture	1.10%
% Volatile Matter	24%
% Ash	23%
%Fixed Carbon	51.40%

Once everything was prepared next step was reduction of iron pellets by non coking coal powder.

3.9 Reduction of pellets

Reduction of various sizes of iron ore pellets were carried out with non coking coal in a stainless steel reactor of size (height-100mm, dia-50mm). Initially the stainless steel reactor was half filled with non coking coal powder of -72# size and then weighed oven dried pellet was placed centrally on this non coking coal powder bed and then the remaining portion of the reactor was filled with coal powder the reactor was covered with a lid having a hole centrally for escape of gases. The reactor was then introduced into the muffle furnace and heated from RT to the reduction temperature of 9500C and soaked there for 1 hour. The reactor was then allowed to cool up to 1500C inside the furnace and then taken out and cooled in air. The weight loss in pellets was recorded by an electronic balance and calculation for % reduction was made.

% Degree of reduction is nothing but the fraction of oxygen removal from the pellet. The % reduction was calculated by using the following formula:-

$$\% \text{ Degree of Reduction} = \frac{\text{Weight loss in iron ore pellet} \quad \text{X } 100}{\text{Total initial } O_2 \text{ present in iron ore pellet with iron}}$$

Chapter 4

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1 For basicity 2.5

It was observed that in the pellet having the basicity 2.5 and fired at 1100^0C, the pellets after reduction fragmented into fines and difficult to find out the reduction percentage.

This is because of:-

1. Improper mixing of iron ore powder and Lime.
2. Excess of lime as free form.
3. Insufficient firing temperature.

4.2 For basicity 1.1

Table: 4.1 Fe_2O_3 = 91.80%

Sl. No.	Size (mm)	Initial Wt. (gm)	Final Wt (gm)	Wt Loss (gm)	% Reduction
1	5	0.3444	0.2562	0.0882	93.04
2	5	0.3186	0.2562	0.081	92.32
3	6	0.3645	0.2376	0.0946	93.84
4	11	3.4418	0.2699	0.8462	89.27
5	11	3.3438	2.5956	7.7968	86.53
6	10	2.3108	2.547	0.5655	88.89
7	15	6.3106	1.7453	1.5706	90.37
8	15	6.3089	4.740	1.4199	81.72
9	14	5.2722	4.889	1.0362	71.36
10	17	8.8544	4.236	1.9444	79.73
11	18	8.6118	6.910	1.6948	71.45
12	16	7.6187	6.917	1.5957	76.05
13	20	16.0916	6.023	2.8502	64.32
14	20	16.3720	13.241	2.809	62.29
15	21	17.1192	13.563	2.4882	52.77
16	22	20.0619	14.631	2.9919	54.15
17	22	21.0127	17.070	2.7617	46.77
18	25	36.0657	18.251	4.7586	47.91
19	26	34.9782	31.3071	4.9746	51.64
20	27	35.2014	30.004	5.0466	53.53
21	27	35.4045	30.9816	4.3974	47.04
22	28	48.4045	31.0087	5.335	40.00
23	30	49.4045	44.026	5.0945	37.44
24	30	48.9971	44.310	4.9711	36.84

Table: 4.2

Initial O_2 Calculation (for 25 mm pellet)

Initial Wt. =36.0657gm

O_2 content = (36.0657*0.918*48) / 160

Sl.No.	Size (mm)	Initial O_2 content (gm)	Final O_2 content (gm)	% Reduction
1	5	0.09484	0.00664	93.04
2	5	0.087742	0.00674	92.32
3	6	0.10038	0.005780	93.84
4	11	0.94787	0.10167	89.27
5	11	0.92088	0.12408	86.53
6	10	0.63639	0.07089	88.89
7	15	1.73794	0.31809	90.37
8	15	1.73747	0.31757	81.72
9	14	1.45196	0.41576	71.36
10	17	2.4385	0.4941	79.36
11	18	2.37168	0.67688	71.45
12	16	2.09818	0.50248	76.05
13	20	4.43152	1.58132	64.32
14	20	4.5088	1.6998	63.29
15	21	4.71462	2.22642	52.77
16	22	5.52505	2.53315	54.15
17	22	5.78689	4.02619	47.77
18	26	9.93249	5.17389	47.91
19	25	9.63311	4.65851	51.64
20	27	9.75039	4.70379	43.53
21	27	9.9703	5.35299	47.04
22	28	13.33059	7.9959	40.00
23	30	13.6559	8.5114	37.44
24	30	13.4939	8.5229	36.84

Table: 4.3 Relation of pellet size with Avg. % reduction

Sl. No.	Pellet size (mm)	Avg. %Reduction
1	5	93.06
2	10/11	88.23
3	15	81.46
4	17	75.74
5	20	59.74
6	22	58.73
7	25	51.34
8	27	45.84
9	28	40.00
10	30	38.09

Fig: 4.1 Graph plotted between Avg. % Reduction Vs Pellet size

The relationship between % reduction and pellet size (5mm,10mm, 12mm, 14mm, 15mm, 18mm, 20mm, 22mm, 25mm, 28mm and 30mm) are illustrated in the table 3 and the above graph. it is observe that as the pellet size increases the % reduction decreases because increase in the radius of pellet increase the diffusion path for the reducing gases and hence increase the time of reduction so according to some engineering models (like Bogdandy and Engell and further reviewed by Tokuda)developed so far, it has been established that as the size of iron ore pellet increases the reduction % decreases.

Chapter 5

CONCLUSION

5. CONCLUSION

As the size of pellet increases the reduction decreases because increase in radius of pellet increases the diffusion path for reducing gases and hence increases the time for reduction of iron oxide to metallic iron.

So as the size of pellet increases the reducibility for iron oxide to metallic iron decreases as shown in the above graph.

From the graph it is also observed that the effective size of pellet for reduction purposes is ranging from 10 to 20mm.

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